SON-1500

PATENT APPLICATION

Attorney Docket No. SON-1500

Date: March 11, 1999

ASSISTANT COMMISSIONER FOR PATENTS
Washington, D.C. 20231

Sir:

Transmitted herewith for filing is the patent application of

Inventor: Masanori IWASAKI

For: IMAGE PICKUP DEVICE

Enclosed are:

☒ Specification and Claim(s).

☒ Oath or Declaration (executed).

☒ FOUR sheet(s) of drawings.

☒ An assignment of the invention to Sony Corporation

☒ Copy of 1 Priority application(s).

☐ Associate Power of Attorney.

The fee has been calculated as shown below:

CLAIMS AS FILED				
FOR	NUMBER FILED	NUMBER EXTRA	RATE	BASIC FEE $380/$760
TOTAL CLAIMS	10-20	0	X $09 $18	$0
INDEP. CLAIMS	2-3	0	X $39 $78	$0
Fee for Multiple Dependent Claims $130/$260				0
			TOTAL FILING FEE	$760.00

SON-1500 PATENT APPLICATION

☒ A Preliminary Amendment is attached.

☐ Verified Statement claiming small entity status is enclosed.

☒ Charge $ 760.00 to Deposit Account No. 18-0013 to cover the filing fee. A duplicate copy of this sheet is enclosed.

☒ The Commissioner is hereby authorized to charge any fees under 37 C.F.R. 1.16 or 1.17 which may be required during the entire pendency of this application, or to credit any overpayment, to Deposit Account No. 18-0013. A duplicate copy of this sheet is enclosed.

☐ A check in the amount of $_____ cover the filing fee is enclosed.

☒ Charge $ 40.00 to Deposit Account No. 18-0013 to cover the recordal fee. A duplicate copy of this sheet is enclosed.

☒ Applicant's undersigned attorney may be reached by telephone in our Washington D.C. Office at

(202) 955-3750.

All correspondence should be directed to our below listed address.

Ronald P. Kananen
Reg. No. 24,104

RADER, FISHMAN & GRAUER, P.L.L.C
1233 20th Street, NW, Suite 501
Washington, DC 20036
Telephone: (202) 955-3750
Facsimile: (202) 955-3751

DC020956

SON-1500 PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In the Patent Application of	)	
	)	
Masanori IWASAKI	)	APPLICATION BRANCH
	)	
Serial No. (Not yet assigned)	)	
	)	
Filed: (Herewith)	)	
	)	
For: IMAGE PICKUP DEVICE	)	

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Prior to the initial examination, please amend the above-identified application as follows:

IN THE SPECIFICATION:

Please amend the specification as follows:

Page 1, line 17, change "(image)" to --image or--.

Page 1, line 20, change "(the" to --(i.e., the--.

Page 2, line 2, change "(the" to --(i.e., the--.

Page 2, line 19, change "more shorten" to --shorten further--.

Page 4, line 23, after "as" insert --the--.

Page 5, line 24, change "MTF" to --the modulation transfer factor (MTF)--.

Page 6, line 19, change "lens, and the" to --lens. The--.

Page 7, line 6, before "length" insert --lens--.

Page 7, line 7, delete "(lens length)".

Page 8, line 13, after "show" insert --the--.

Page 8, line 17, after "represents" insert --a--.

Page 9, line 12, change "(surfaces)" to --or surfaces--.

Page 10, line 2, change "(focused)" to --or focused--.

Page 10, line 13, after "by" insert --an--.

Page 10, line 22, change "enter to" to --enter into--.

Page 11, line 4, change "is" (both occurrences) to --are--.

Page 11, line 8, change "(surfaces)" to --or surfaces--.

IN THE CLAIMS:

Please amend the claims as follows:

Claim 1, line 4, after "axis" insert --of the lens--.

Claim 3, line 3, change "the" to --a--.

Claim 4, line 3, change "the" to --a--.

Claim 5, line 2, change "of the" to --end--.

Please add new claims 9 and 10 as follows:

9. The image pickup device as claimed in claim 1, wherein said lens has a cylindrical shape having a light incident face at one end along said optical axis and said imaging face at said opposite end.

10. The image pickup device as claimed in claim 9, wherein curvature is provided to one or both end surfaces of said refractive index distribution lens.

REMARKS

This Preliminary Amendment is requested to make minor clerical changes in the specification and claims. No new matter has been added. Entry of this amendment is requested.

Respectfully submitted,

DATE: March 11, 1999

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DC020954

SON-1500 PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In the Patent Application of	
Masanori IWASAKI	APPLICATION BRANCH
Serial No.: (Not yet assigned)	
Filed: (Herewith)	
For: IMAGE PICKUP DEVICE	

LETTER TO OFFICIAL DRAFTSPERSON

Assistant Commissioner of Patents
Washington, DC 20231

Sir:

Subject to the approval of the Examiner, please amend the drawings as shown in red in the accompanying paper. Specifically, in Fig. 3, change the word "POSTION" to --POSITION--.

Respectfully submitted,

Dated: March 11, 1999

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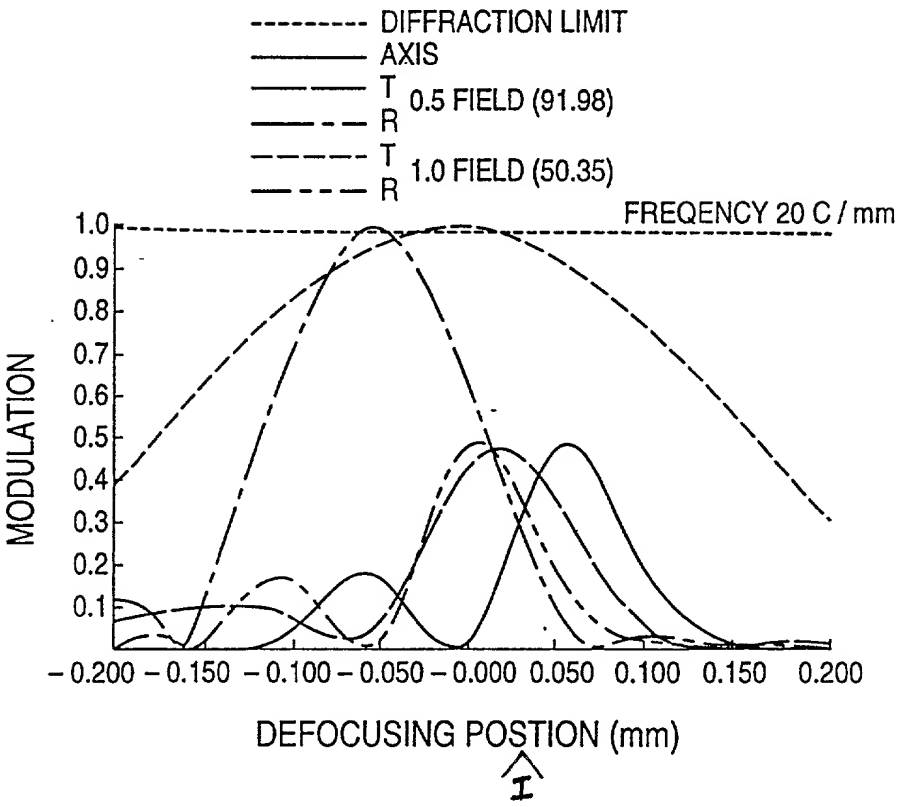
DC020960

FIG. 3


DIFFRACTION LIMIT
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0.5 FIELD (91.98)
T
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1.0 FIELD (50.35)
FREQENCY 20 C / mm
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DEFOCUSING POSTION (mm)
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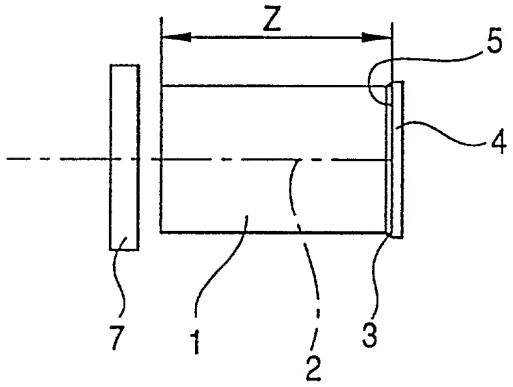
FIG. 4


Z
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4
7
1
2
3

FIG. 3

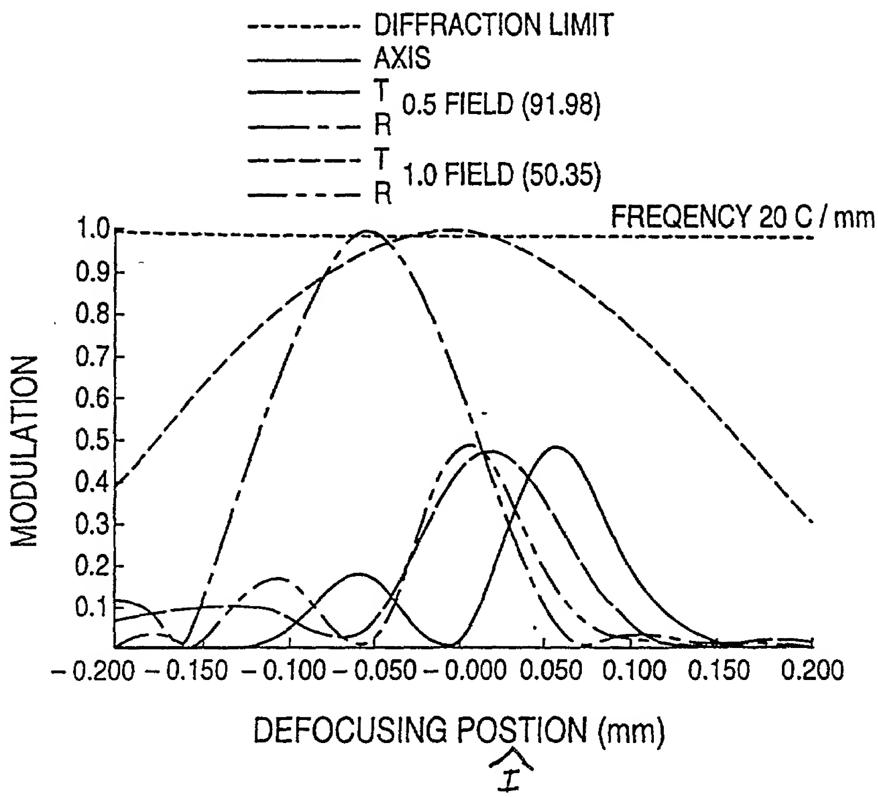
DIFFRACTION LIMIT
AXIS
T
R
0.5 FIELD (91.98)
T
R
1.0 FIELD (50.35)
FREQENCY 20 C / mm
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
MODULATION
– 0.200 – 0.150 – 0.100 – 0.050 – 0.000 0.050 0.100 0.150 0.200
DEFOCUSING POSTION (mm)

FIG. 4

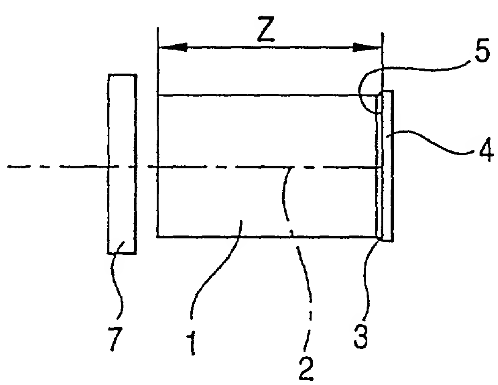
Z
5
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IMAGE PICKUP DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an image pickup device comprising an image pickup element and a lens for focusing an image onto the imaging face of the image pickup element.

2. Description of the Related Art

Recently, an image pickup device comprising a solid-state image pickup element and a lens for focusing an image onto the imaging face thereof has been applied to a camera. An optical lens having uniform refractive index is used as a lens for such an image pickup device as described above.

In the image pickup device using the lens having uniform refractive index, an optical distance which is extremely large although it is finite is required between the lens and the solid-state image pickup element in order to converge and focus (image) refracted light beams onto the imaging face of the solid-state image pickup element. Accordingly, the sum of the thickness of the lens and the imaging distance is needed as the optical distance between a first face (the face at the light incident side) of the lens and the imaging face of the solid-state image pickup element.

In the conventional image pickup device as described above, since the total of the lens thickness and the imaging distance

is needed as the optical distance between the lens first face (the incident-side face) and the imaging face of the solid-state image pickup element, and thus it is very difficult to shorten the overall length of the optical system. Therefore, requirements of compact design for the image pickup device and the camera using it have never been satisfied.

According to the above-described conventional image pickup device, when a lens holder is used to secure a lens so as to be spaced from the image pickup element at a proper interval while a predetermined positional relationship is kept between the lens and the image pickup element, an error of the positional relationship between the lens and the lens holder and an error of the positional relationship between the lens holder and the solid-state image pickup element may occur as a fabrication error, and thus it is difficult to reduce the error.

SUMMARY OF THE INVENTION

The present invention has been implemented to overcome the problem of the conventional image pickup device, and has an object to more shorten the overall length of an image pickup device comprising a lens and an image pickup element, and reduce the error of the positional relationship between the lens and the image pickup element.

In order to attain the above object, an image pickup device according to the present invention is characterized in that a refractive index distribution lens having a refractive index

distribution which is substantially proportional to the square of the distance from the optical axis in a cross-section vertical to the optical axis is provided as an imaging lens in the neighborhood of the imaging face of the image pickup element.

According to the image pickup device of the present invention, since the refractive index lens is used as the lens, an image at infinity which is incident as parallel rays of light from the end face of the lens incident side is imaged on the end face of the lens emission side when the length (thickness) of the lens is set to a meandering period $P = 0.5\pi + n\pi$ ($n = 0, 1, 2, \ldots$). Accordingly, the image is imaged on the imaging face of the image pickup element located in the neighborhood of the end face of the lens emission side, and thus it is unnecessary to set a large gap between the lens and the image pickup element. Therefore, the length of the optical system can be reduced, and the design of the image pickup device can be improved to be more compact in size and thinner in thickness.

Further, the lens can be provided in the neighborhood of the image pickup element, and thus the positional relationship between the image pickup element and the lens can be fixed by adhesion with organic solvent or the like, whereby an error factor causing the positional error of the lens to the image pickup element can be reduced and thus the positioning precision can be enhanced.

The image pickup device of the present invention is basically characterized in that a refractive index distribution lens having a refractive index distribution which is substantially proportional to the square of the distance from the optical axis in cross-section vertical to the optical axis is provided as an imaging lens in the neighborhood of the imaging face of an image pickup element. The lens length is preferably set to a meandering period $P = 0.5\pi + n\pi$ ($n = 0, 1, 2, \ldots$). Particularly, it is preferable that the lens length is as small as possible (for example, zero) because the lens length can be shortened.

The image pickup device of the present invention can be embodied in such a manner that the refractive index distribution lens and the image pickup element are held by a holder to regulate the positional relationship between the refractive index distribution lens and the image pickup element. However, it may be embodied in such a manner that the refractive index distribution lens is directly adhesively attached to the image pickup element. In this case, the positional relationship between the refractive index distribution lens and the image pickup element can be controlled with extremely high precision if material which has no adverse effect on the lens and the image pickup element is merely selected as adhesive agent.

Further, an optical thin film for reflecting infrared rays may be provided at the light incident face of the refractive

index distribution lens, or absorption means for absorbing infrared rays may be provided at the light incident face side of the refractive index distribution lens. With this structure, the infrared rays can be intercepted.

Further, a lens which is provided with a curvature at one end face side or both the end face sides thereof may be used as the refractive index distribution lens. In this case, the optical characteristic based on the refractive index distribution is varied by the curvature, and the combined optical characteristic of the optical characteristic based on the refractive index distribution and the optical characteristic based on the curvature becomes the optical characteristic of the lens. As described above, the present invention has various modes.

The "image pickup element" of the present invention means any member which can receive an image of rays of light from a subject and output the electrical signal corresponding to the image, such as a CCD (charge-coupled device), a CMOS image sensor or the like.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional view showing an embodiment of an image pickup device according to the present invention;

Fig. 2 is a diagram showing the relationship between spatial frequency and modulation of MTF of the optical characteristic obtained by the image pickup device of the

present invention;

Fig. 3 is a diagram showing the relationship between defocusing position and modulation of MTF of the optical characteristic obtained by the image pickup device of the present invention;

Fig. 4 is a cross-sectional view showing another embodiment of the image pickup device of the present invention; and

Figs. 5A to 5C are cross-sectional views showing various modifications of a refractive index distribution lens of the image pickup device according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment according to the present invention will be described hereunder with reference to the accompanying drawings.

Fig. 1 is a cross-sectional view showing an embodiment of an image pickup device according to the present invention.

In Fig. 1, reference numeral 1 represents a refractive index distribution lens, and the refractive index distribution lens 1 is designed in a cylindrical shape and has a refractive index distribution which is substantially proportional to the square of the distance from an optical axis 2 in a cross-section vertical to the optical axis 2. The refractive index distribution lens 1 adheres to an imaging face 5 of a solid-state image pickup element 4 at the end face of the light emission

side thereof by thin and transparent adhesive agent 3 formed of organic solvent. Reference numeral 6 represents an infrared-ray cut filter film formed on the light incident face of the refractive index distribution lens 1, and the filter 6 is formed by deposition and serves to reflect infrared rays.

The length Z of the refractive index distribution lens 1 (lens length) is expressed by the following equation when the refractive index distribution constant $\sqrt{A} = 0.43$, the refractive index N on the optical axis (different from "n" in the equation expressing the meandering period P) = 1.658 and the meandering period $P = 0.5\pi$ (i.e., for n = 0 in the equation of the meandering period P):

Z = meandering period P/refractive index distribution constant

$= (0.5\pi)/\sqrt{A} = 3.653$mm.

In this case, the calculation is made under the condition that the thickness of the adhesive agent 3 is neglected, the emission-side end face of the refractive index distribution lens 1 is brought into direct contact with the imaging face and the existence of the infrared-rays cut filter 6 (thickness, characteristic) is neglected. In the above equation, A represents a focusing parameter. The lens diameter is set to 1.8mm, and thus the refractive index distribution lens 1 of this embodiment is optimum to a 1/10-inch image pickup element 4. This is because the length of the diagonal line of the 1/10-inch image pickup element 4 is equal to 1.8mm. That is, such a lens

1 is provided on a 1/10-inch image pickup element 4 to obtain an image of a diagonal view angle of 100 degrees. In addition, an infrared-ray image can be removed from the image thus obtained because the infrared-ray cut filter 6 is provided.

In Fig. 1, the on-axis optical path and the peripheral path are shown. Light beams on the on-axis optical path travel in parallel to the optical axis 2 of the lens 1 and are incident to the refractive index distribution lens 1. The incident light beams on the on-axis optical path are converged onto the end face of the emission side of the lens 1 or to a cross-point between the optical axis and the on-axis optical path behind the emission-side end face of the lens 1.

Figs. 2 and 3 show MTF (modulation transfer factor) of the optical characteristic obtained at this time. In Fig. 2, the abscissa represents spatial frequency (cycle/mm) and the ordinate represents modulation, and in Fig. 3, the abscissa represents defocusing position (mm) and the ordinate represents modulation.

The above-described image pickup device is an embodiment of the present invention, and the present invention may be embodied in various modes. First, in order to cut infrared rays, infrared rays may be reflected by an infrared-ray cut filter film 6, or an optical element 7 for absorbing infrared rays may be provided at the light incident face side of the refractive index distribution lens 1 to cut infrared rays as shown in Fig.

4.

As shown in Figs. 5A to 5C, a lens provided with curvature at both or one of the light incident face and the light emission face thereof (as indicated by reference numerals 1a, 1b, 1c in Figs. 5A to 5C) may be used as the refractive index distribution lens 1.

In this case, the combined optical characteristic of the optical characteristic based on the refractive index distribution and the optical characteristic based on the curvature becomes the characteristic of the refractive index distribution lens 1. That is, one or both of the end faces (surfaces) of the refractive index distribution lens is provided with curvature, the lens effect can be also obtained by the curvature. Accordingly, the same lens effect can be achieved with a thinner refractive index distribution lens by the total effect of the lens effect based on the refractive index distribution and the lens effect based on the curvature. Accordingly, the more compact and thinner design of the image pickup device can be achieved.

According to the image pickup device of the first aspect of the present invention, a single refractive index distribution lens having a refractive index distribution which is substantially proportional to the square of the distance from the optical axis in a cross-section vertical to the optical axis is used as an imaging lens, so that an image at infinity which

is incident from a lens incident-side end face as parallel rays of light are imaged (focused) on the end face of the light emission side of the lens. Accordingly, the imaging face of the image pickup element can be positioned in the neighborhood of the refractive index distribution lens, and it is unnecessary to provide a gap between the lens and the image pickup element. Accordingly, the length of the optical system can be shortened, and the miniaturization of the image pickup device can be achieved.

Further, according to the image pickup device of the second aspect of the present invention, the refractive index distribution lens is adhesively attached in the neighborhood of the imaging face of the image pickup element by adhesive agent, whereby the error factor in association with the positioning between the refractive index lens and the image pickup element is reduced and thus the positioning can be performed with extremely high precision.

According to the image pickup device of the third aspect of the present invention, the optical thin film for reflecting infrared rays is provided to the light incident face of the refractive index distribution lens, whereby infrared rays which are about to enter to the lens are reflected by the thin film to thereby prevent incidence of infrared rays into the image pickup element.

According to the image pickup device of the fourth aspect

of the present invention, the optical element for absorbing infrared rays is provided to the light incident face side of the refractive index distribution lens, whereby infrared rays which is about to enter the lens is absorbed by the element to thereby prevent incidence of infrared rays into the image pickup element.

According to the image pickup device of the fifth aspect of the present invention, one or both of the end faces (surfaces) of the refractive index distribution lens is provided with curvature, and thus the lens effect can be also obtained by the curvature. Accordingly, the same lens effect can be obtained with a thinner refractive index distribution lens by the total effect of the lens effect based on the refractive index distribution and the lens effect based on the curvature. Accordingly, the more compact and thinner design can be performed on the image pickup device.

WHAT IS CLAIMED IS:

1. An image pickup device, characterized in that a refractive index distribution lens having a refractive index distribution which is substantially proportional to the square of the distance from the optical axis in a cross-section vertical to the optical axis is provided as an imaging lens in the neighborhood of an imaging face of an image pickup element.

2. The image pickup device as claimed in claim 1, wherein said refractive index distribution lens is adhesively attached to said imaging face of said image pickup element by adhesive agent.

3. The image pickup device as claimed in claim 1, wherein an optical thin film for reflecting infrared rays is provided on the light incident face of said refractive index distribution lens.

4. The image pickup device as claimed in claim 1, wherein infrared-ray absorption means for absorbing infrared rays is provided at the light incident face side of said refractive index distribution lens.

5. The image pickup device as claimed in claim 1, wherein curvature is provided to one or both of the surfaces of said refractive index distribution lens.

6. An image pickup device, characterized in that a single refractive index distribution lens is provided as an imaging lens in the neighborhood of an imaging face of an image

pickup element, and the lens length of said refractive index distribution lens is set to a value obtained by dividing a meandering period $P = 0.5\pi + n\pi$ ($n = 0, 1, 2, \ldots$) by a refractive index distribution constant of said refractive index distribution lens for a use wavelength of said image pickup device.

7. The image pickup device as claimed in claim 6, wherein the refractive index distribution of said refractive index distribution lens is substantially proportional to the square of the distance from the optical axis in a cross-section vertical to the optical axis.

8. The image pickup device as claimed in claim 6, wherein said refractive index distribution lens is adhesively attached to said imaging face by adhesive agent.

ABSTRACT OF THE DISCLOSURE

In an image pickup device, a single refractive index distribution lens having a refractive index distribution which is substantially proportional to the square of the distance from an optical axis in a cross-section vertical to the optical axis is provided as an imaging lens in the neighborhood of the imaging face of an image pickup element. Specifically, the positional relationship between the image pickup element and the lens is fixed by adhesion of organic solvent or the like. Further, an infrared-ray cut filter is formed on the light incident face of the refractive index distribution lens.

FIG. 1

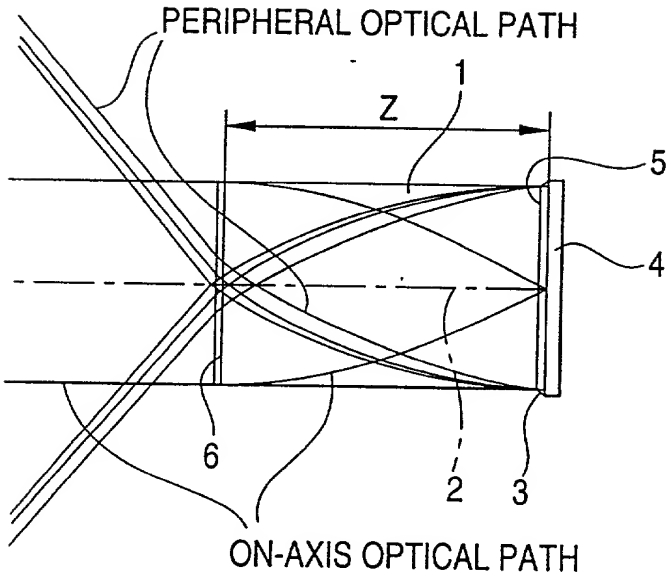
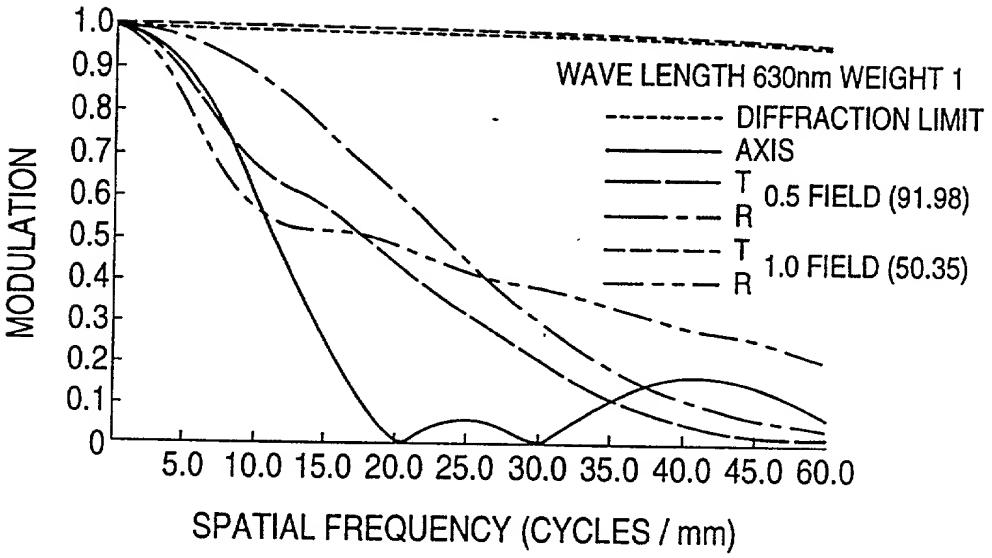


FIG. 2


1.0
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0.5
0.4
0.3
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0
MODULATION
5.0 10.0 15.0 20.0 25.0 30.0 35.0 40.0 45.0 60.0
SPATIAL FREQUENCY (CYCLES / mm)
WAVE LENGTH 630nm WEIGHT 1
DIFFRACTION LIMIT
AXIS
T
R
0.5 FIELD (91.98)
T
R
1.0 FIELD (50.35)

FIG. 3

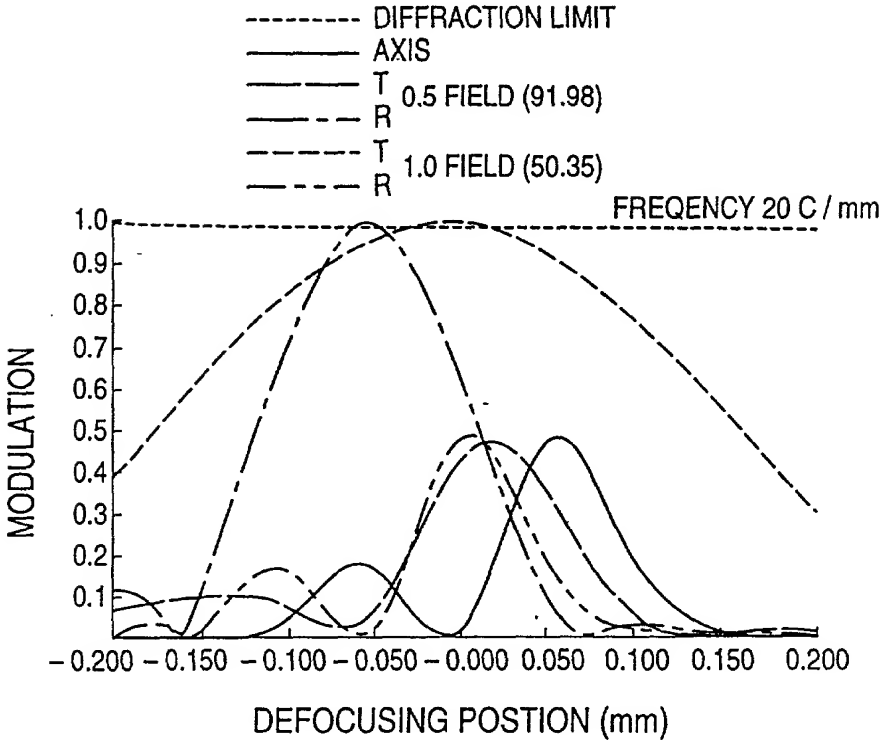
DIFFRACTION LIMIT
AXIS
T
R
0.5 FIELD (91.98)
T
R
1.0 FIELD (50.35)
FREQENCY 20 C / mm
MODULATION
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.200 -0.150 -0.100 -0.050 -0.000 0.050 0.100 0.150 0.200
DEFOCUSING POSTION (mm)

FIG. 4

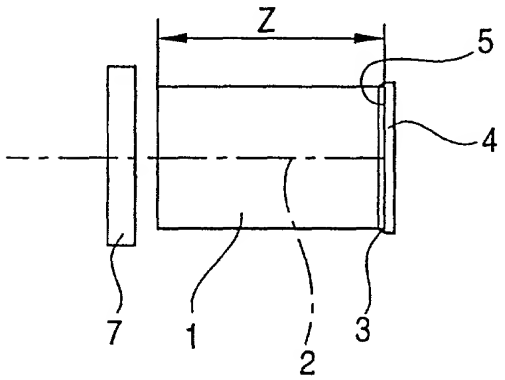
Z
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FIG. 5A

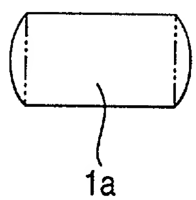


FIG. 5B

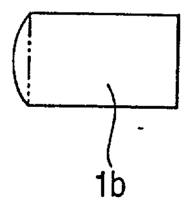
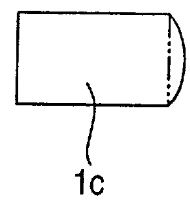


FIG. 5C



Attorney's Docket No. SON-1500

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION
English Language Declaration

As below named inventors, we hereby declare that:

Our residence, post office address and citizenship are as stated below next to our names.

We believe we are the original, first and joint inventors of the subject matter which is claimed and for which a patent is sought on the invention entitled
IMAGE PICKUP DEVICE

the specification of which

(check one)

X is attached hereto.

was filed on _____ as

Application Serial No. _____
and was amended on _____

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent of inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)			Priority Claimed	
P10-065966	Japan	17/03/1998	X	
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No

We hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 and 1.63(d) which became available between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)

We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Attorney's Docket Number: SON-1500

English Language Declaration

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

Ronald P. Kananen, Reg. No. 24,104; Ralph T. Rader, Reg. No. 28,772; Michael D. Fishman, Reg. No. 31,951, Richard D. Grauer, Reg. No. 22,388; Joseph V. Coppola, Sr., Reg. No. 33,373; Michael B. Stewart, Reg. No. 36,018; Steven L. Nichols, Registration No. 40,326

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Washington, D.C. 20036

Direct telephone calls to:

Ronald P. Kananen, Esq.
(202) 955-3750

Full name of first joint inventor	MASANORI IWASAKI	
Inventor's signature	Masanori Iwasaki	Date March. 1, 1999
Residence	TOKYO, JAPAN	
Citizenship	JAPANESE	
Post Office Address	c/o SONY CORPORATION 7-35, KITASHINAGAWA 6-CHOME, SHINAGAWA-KU,	
	TOKYO, JAPAN	
Full name of second joint inventor		
Second Inventor's signature		Date
Residence		
Citizenship	JAPANESE	
Post Office Address	c/o SONY CORPORATION 7-35, KITASHINAGAWA 6-CHOME, SHINAGAWA-KU,	
	TOKYO, JAPAN	
Full name of third joint inventor		
Third Inventor's signature		Date
Residence		
Citizenship	JAPANESE	
Post Office Address	c/o SONY CORPORATION 7-35, KITASHINAGAWA 6-CHOME, SHINAGAWA-KU,	
	TOKYO, JAPAN	

~~(Supply similar information and signature for subsequent joint inventors.)~~